International Journal of Metallurgical &
Materials Science and Engineering (IJMMSE)
ISSN(P): 2278-2516; ISSN(E): 2278-2524
Vol. 5, Issue 2, Apr 2015, 7-16
© TJPRC Pvt. Ltd

TRANS STELLAR • Journal Publications • Research Consultancy

ASSESSMENT OF GRANULOMETRIC COMPOSITION OF ORE MATERIALS AND ORE LOAD ON DEVELOPMENTAL REGENERATIVE PROCESSES IN THE PERIPHERAL ZONE OF THE BLAST FURNACE

S. O. JIMOH, S. A. ZAGAYNOV, A. V. LOZOVICH & L. U. GILEVA

Department of Metallurgy of iron and Alloys, Institute of Material Sciences and Metallurgy, Ural Federal University (named after the first President of Russia Boris Yeltsin), Yekaterinburg, Russia

ABSTRACT

A study was carried to develop model equations for assessing impact of ore materials and ore loading in the development and recovery of heat in the peripheral zone of the blast furnace. Mathematical models (using essential regression excel package) was developed to help facilitate data analysis. The results from data of the particle size distribution of the agglomerates table revealed that within agglomerates fractions content of -5mm and +40mm not more than 5% each, and content of fractions 5mm-25mm over 75% could be used optimally as peripheral zone blast furnace thermal control state. It was within this agglomerate fractions content that average value of the specific flow resistance (ΔPw) is reduced to 575 and the maximum value is less than 1120, while the average value of the initial rate of recovery is 2746, and the lowest is 1065 necessary for efficient peripheral zone of blast furnace were calculated.

KEYWORDS: Blasts Furnace, Peripheral Zone, Ore Load, Indirect Reduction, Degree of Use of CO, Heat Transfer

NOMENCLATURE

ΔR_i - degree of indirect reduction;

CO_Σ - the total content of CO and CO2 in the gas, m3 / m3;

H_Σ - total content of H_2 and H_2O in the gas, M^3 / M^3; the degree of the use of CO and H2 (respectively), the proportion of units .;

Vr - output gas per unit time;

P - productivity of the blast furnace per unit time;

δ - the specific (per 1 ton. cast iron) the amount of oxygen gasified iron oxides.

ΔP - Changing the amount of gas;

λ - coefficient of resistance;

d - equivalent diameter pieces of layer m;

ε- bed porosity, m3 / m3;

T-is the temperature, K;

P - pressure, Pa;

ρ_0- gas density, kg / m 3;

w_0 - gas velocity.

Lower symbol 0 means the value is referenced to normal conditions. ΔV_{Γ} - the change amount of gases

The upper symbol* means that the calculation is performed for the changed conditions of the furnace.

ε_k, ε_i - large porosity and the i-th fraction;

g_k, $_{gi}$ - the contents of the large and the i-th fraction;

d_k, d_i - diameter of the pieces of the big and the i-th fraction.

$$\frac{\Delta \varphi}{\Delta \tau}$$

Here - increase the degree of reduction per unit of time;

k - reaction rate constant, which depends on the temperature and pressure of the gas composition of the reducing agent;

r_0 - initial radius of the piece;

ρ_0 - density of the piece.

S - surface area pieces which fashionable calculated using equation (9)

g_i - the share of the i-th fraction;

d_i - diameter piece of the i-th fraction;

$\Delta P_{Э}$ - specific flow resistance

v - velocity of chemical reactions mol / l • sec;

x - the concentration of substance in mol / l;

x_p - equilibrium concentration in mol / l;

k – rate constant, c-^{1};

S - surface area pieces;

τ – time, c;

S-cross section ring located at the periphery, m^2;

H - height of the upper-stage heat transfer, M;

P_d – total capacity, T/d.;

γ_{sp} - specific volume of the material, m^3 / t of pig iron;

f - coefficient charge, of a unit.

W_{ch} - rate of descent of the speed, m/s;

C_{ap} - the apparent heat capacity of the charge, kJ/kg.k;

ρ_0 - bulk density of the charge, kg/m^3;

α_v - heat transfer coefficient, W/m^{3}K;

m - ratio of specific heats of the charge flows and gases.

INTRODUCTION

The practice of conducting the blast furnace is focused on creating the conditions under which the maximum degree of the use of CO in the blast furnace. This is achieved under the maximum permissible load of the central and peripheral zones of the furnace and work with an open center. However, when excessively loaded in the periphery of the primary slag may be a high content of FeO. FeO content in the primary slag depends on its share of recoverability by direct reduction reactions of the liquid phase.

Analysis of the known diagrams slag systems [4-6] showed that the FeO content in the primary slag in the range 10 - 40% for each percentage point increase of the melting point of FeO oxide component is reduced by 8 - 12 ^{o}C. The low melting point oxide component does not contribute to create stable near shoulders and bosh, which leads to increased heat losses and reduces the duration of the blast furnace.

The problem is solved by evaluating the impact of the factors considered in the development of the indirect restoration. In analyzing the change in the degree of indirect reduction is linearized equation [1,2].

$$\Delta R_i = \frac{CO_\Sigma \cdot \eta_{CO} + H_\Sigma \cdot \eta_{H2}}{2P\delta} \cdot \Delta V_\Gamma + \frac{V_\Gamma \cdot (CO_\Sigma \cdot \Delta\eta_{CO} + H_\Sigma \Delta\eta_{H2})}{2P\delta} \quad (1)$$

The first component of equation (1) takes into account the influence of the amount of gases in the development of indirect reduction, and the second component takes into account the thermodynamics and kinetics of reactions of reduction of iron oxides. Changing the amount of gas in the solution of the above problem can be determined by solving the equation in relative coordinates Ergon [7].

$$\Delta P = \lambda \cdot \frac{h}{d_э} \cdot \frac{1-\varepsilon}{\varepsilon^3} \cdot \frac{T}{T_0} \cdot \frac{P_0}{P} \cdot \frac{\rho_0 \cdot w_0^2}{2}, \quad (2)$$

In relative coordinates, the equation for calculating the change amount of gases will have the form

$$\Delta V_\Gamma = V_\Gamma \cdot \left(\sqrt{\frac{(1-\varepsilon^*) \cdot \varepsilon^3 \cdot d_Э}{(1-\varepsilon) \cdot \varepsilon^{3*} \cdot d_Э^*}} - 1\right) \quad (3)$$

To calculate the porosity of the layer, as in the baseline, and at change of ore loading and (or) the particle size distribution of the burden, used well-known equation [3]:

$$\varepsilon = 1 - (1-\varepsilon_к) \cdot g_к - \Sigma(1-\varepsilon_i) \cdot g_i \cdot [1{,}582 - 2{,}416 \cdot \frac{d_i}{d_K} + 1{,}485 \cdot (\frac{d_i}{d_K})^2 + 0{,}18 \cdot \frac{g_i}{g_R} - 0{,}015 \cdot (\frac{g_i}{g_K})^2] \quad (4)$$

The equivalent diameter is calculated by the equation:

$$d_э = \frac{1}{\Sigma g_i / d_i} \tag{5}$$

Effect of particle size distribution of the agglomerate on the development of processes of heat exchange and recovery in the peripheral zone of the blast furnace is taken into account through specific flow resistance of the charge calculated by the equation

$$\Delta P_Ш = \frac{1}{d_Э} \cdot \frac{(1-\varepsilon)}{\varepsilon^3} \tag{6}$$

The second component of the equation (1) takes into account the effect of the rate of recovery of ore component. As a working hypothesis assumed that the evaluation of the influence of particle size distribution of iron ore materials in the recovery rate can be described by a shrinking core model [8].

$$\frac{\Delta\varphi}{\Delta\tau} = \frac{k}{r_0 \cdot \rho_0} \tag{7}$$

The average radius of the pieces in the layer (r0) can be obtained from empirical equations relating surface pieces (S) with fractional composition of the agglomerate [8].

$$r_0 = \sqrt{\frac{S}{4 \cdot \pi}} \tag{8}$$

It is generally recognized that the most reduction reactions in a blast furnace does not reach equilibrium. Influence of recovery time on the deviation of the concentration of the reaction products from the equilibrium expressed in terms of the rate of reaction [8]:

$$\mathrm{v} = \frac{\mathrm{dx}}{\mathrm{d}\tau} = \mathrm{k}(\mathrm{x} - \mathrm{x_p}) \tag{10}$$

Integrating this expression allows to obtain the dependence of the deviation with respect to the equilibrium concentration of the substance of the reaction time:Time is determined by the height of the zone:

$$\tau = \frac{S \cdot H}{P \cdot \gamma_{sp}(1-f)} \cdot 24 \tag{11}$$

The height of the upper zone of the furnace is calculated from the known theory of heat transfer in the blast furnace eq. (12)

$$H = \frac{2 \cdot w_{ch} \cdot c_{ap} \cdot \rho_{ch}}{\alpha_v \cdot (1-m)} \tag{12}$$

The equations for calculating the temperature of flue gases peripheral based on the laws of heat transfer are as follows.

$$m = 0.5(1 + \frac{c_{ch} \cdot G_{ch}}{c_g \cdot V_g}) \quad (13)$$

$$m = \frac{t_0 - t_{ic}}{t_{ro} - t_{ch}}; \quad (14)$$

$$\Delta m = -(m - 0.5)(\frac{\Delta(c_{ch} \cdot G_{ch})}{c_{ch} \cdot G_{ch}} - \frac{\Delta(c_g \cdot Vg)}{c_g \cdot V_g}) \quad (15)$$

$$\Delta t_G = \Delta m(t_{sho} - t_{shk}); \quad (16)$$

In this work, attempts were made to determine the influence of particle size distribution of ore materials and ore loading on the development of regenerative processes in the peripheral zone of the furnace.

Procedure

To analyze the effect of agglomerate size distribution on the specific flow resistance layer (ΔPsh) and the initial rate of reduction of iron oxides (Δm / Δt) used the data on particle size distribution of the skip sinter. Maximum, minimum and average values of the content of the fractions, as well as calculated indicators are provided in Table 1.

Table 1: Data of the Particle Size Distribution of the Agglomerates

	Fractional Composition, %					$\Delta P_ш$	$\Delta m/\Delta t$
	5-10	10-25	25-40	40	-5		
Minimum value	4,00	28,90	6,90	1,90	0,90	234	945
Maximum value	42,50	58,30	31,10	24,60	11,50	1811	5014
Average value	22,04	45,01	14,87	12,77	5,32	842	2732

Considered when modeling options that displays one or the other faction, and the share of other factions increases proportionally.

As a result, the calculations indicated that the content of fraction + 40 in the agglomerate reduced permeability layer while reducing the initial rate of recovery. With the exclusion of the agglomerate fraction +40 in these agglomerates average value of the specific flow resistance ($\Delta P_ш$) is reduced to 575, and the maximum value is less than 1120, while the average value of the initial rate of recovery is 2746, and the lowest in 1065.

Effect of -5 mm fraction significantly affects the specific flow resistance when its content exceeds 5%. Correlation equation relating the ($\Delta P_ш$) with a share fraction -5 (α-5) has the following form ΔP = 125 + 134 α-5, and for which there is no agglomerates fraction $\Delta P_ш$ 40 = 93 + 79 α-5. Comparison of coefficients of these equations leads to the conclusion that the absence of the fraction +40 in the fraction of fines less effect on the gas permeability of the layer. At the same time, the coefficients in the equations of the conveners of the initial rate of recovery with a share of fines vary by no more than 20% relative.

The best conditions, both in terms of gas dynamics, and in terms of the initial rate of recovery observed in the total content of fractions 5-10 and 10-25 of more than 75%. For these agglomerates average value of the specific flow

resistance is 817, and the average value of the initial rate of recovery 3275. In this case, the maximum value is 1210 $\Delta P_{ш}$, and the minimum value $\Delta m / \Delta t$ 2706.

Thus, thermal control state of the peripheral zone of the furnace should be encouraged content agglomerates with fractions -5 mm and +40 mm is not more than 5% each, and contents of fractions 5-25 over 75%.

Change of ore load in the peripheral zone of the furnace is the main way to influence the temperature field and the recovery processes. By using the proposed method of calculation determined the effect of varying the load of ore at 0.1 t / t of ore at different loads and different particle size distribution of the agglomerate. The results of the calculations are shown in Figure 1-3.

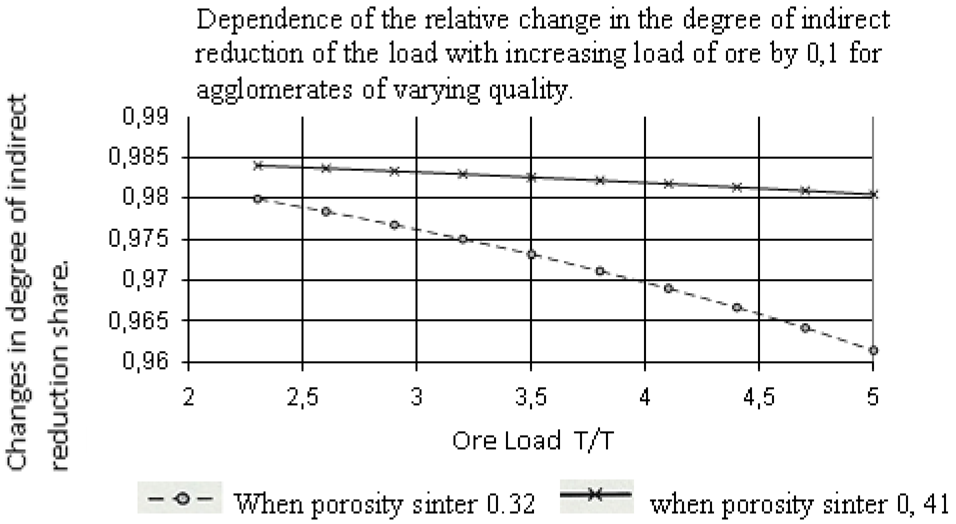

Figure 1

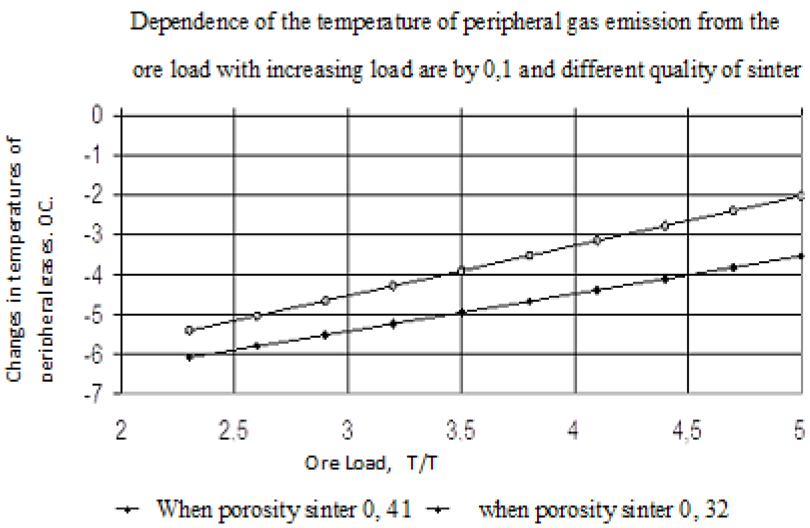

Figure 2

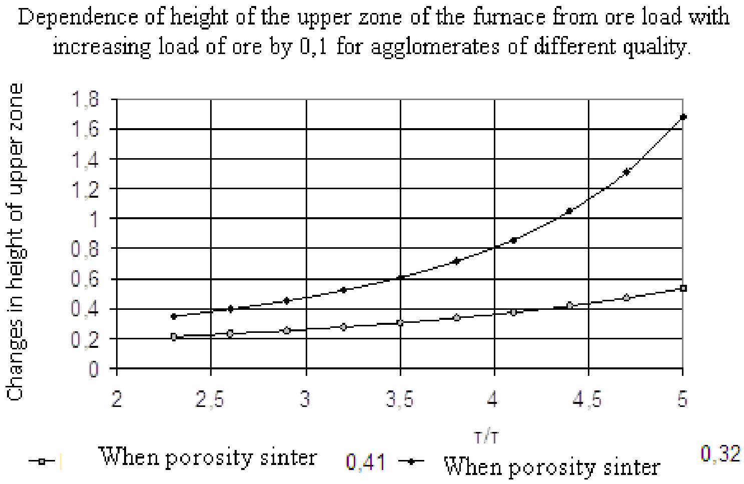

Figure 3

RESULTS AND DISCUSSIONS

The results in these drawings show the following data.

- Image ore load leads to increase in the length of the upper zone of the furnace, lower peripheral gas temperature and reduce indirect restoration.
- The greatest changes are observed at the low quality of sinter.
- At low loads ore change height of the upper zone of the furnace is minimal, at the same time, the change in temperature of peripheral gas emissions as much as possible.
- The fact that the decrease in temperature is accompanied by a decrease in peripheral gas indirect restoration can be considered as an indicator of the temperature of the periphery of the indirect restoration.
- Reduced quality of sinter lowers the temperature of the peripheral gases.

A relationship between temperature and resistance periphery is confirmed by the data of the blast furnaces. In Figure 4 shows the relationship between temperature and heat removal from the periphery refrigerators shoulders. Figure 5 dynamic changes in body temperature and refrigerator temperature of peripheral gases.

The relationship of heat removal refrigerators shoulders with peripheral temperature gases

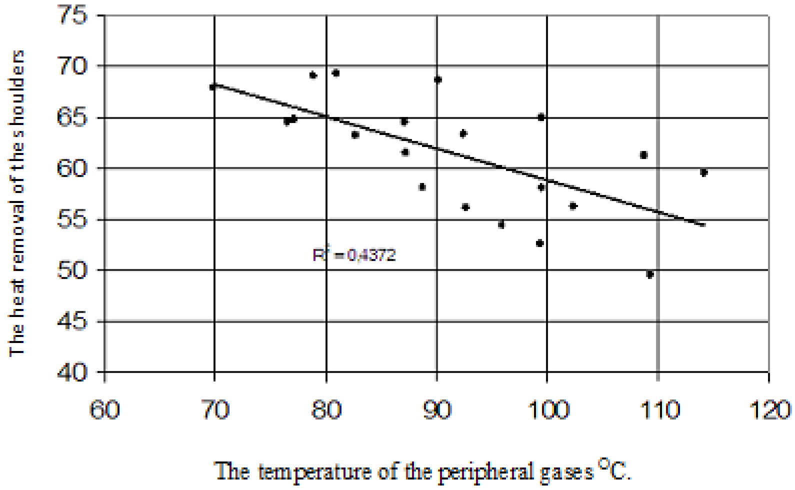

Figure 4

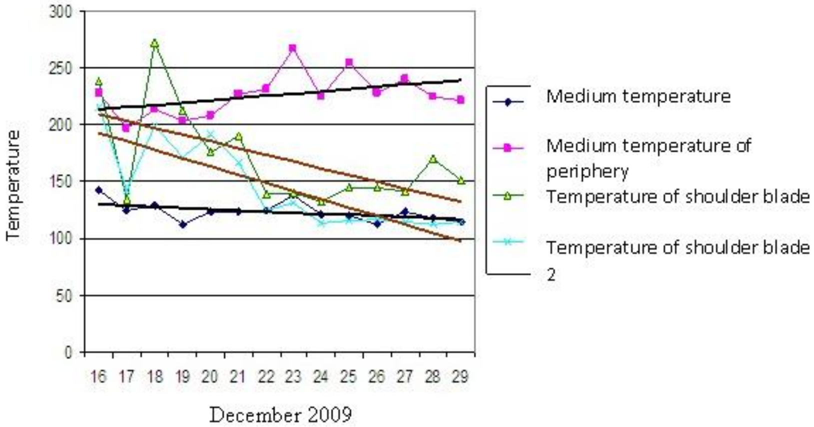

Figure 5: Blast Furnace Instrumentation Data

CONCLUSIONS

The result of research is a developed method of assessing the impact of stress on the development of the ore and heat recovery in the peripheral zone of the blast furnace. Found that the best conditions for iron oxide reduction is achieved when the content of fractions 5-25 of more than 75%. When the proportion of fractions - 5 and +45 should not exceed 5%.It is shown that the influence of the ore load most significantly manifested in the poor quality of sinter. When the temperature drops peripheral gases there is an increase of thermal stress on shoulders refrigerators. This fact allows us to use this information to control the distribution of material in the cross section of a blast furnace.

REFERENCES

1. N. A. Spirin, Y. V. Ipatov, VI Lobanov, V.A. Krasnobaev, V. V. Lavrov, V. Y. Rybolovlev, V. S. Shwidkiy, S. A. Zagaynov, O. P. Onorine. Ed. N.A.Spirina. Ekaterinburg: Ural State Technical University Information Systems in the Metallurgy, 2001. 617 p.

2. Gileva L.Y., Yaroshenko Zagaynov S.A., et al .// Proceedings of the universities, Iron and Steel Development of a mathematical model with a variable structure for analyzing and forecasting the performance of the blast furnace

on the basis of accounting data , 1993, № 4 , p. 51-55.

3. Kovshov V.N. Palaganov A.I. .., Ostyak V.G. etc. .// Metallurgy Investigation of the porosity of multi-component batches / 1977.-vol..53..34-37p.
4. (I. D Balon al.) Ed. E.F. Vegmann. - Moscow: Metallurgy, Blast Furnace: A Handbook in 2 volumes. T. 1: Preparing ore and blast furnace, 1989 - 495 p.
5. V. G. Voskoboynikov, N. E. Dunayev, A. G. Mihalevitch et al. - M.: Metallurgy Properties of liquid blast furnace slag /, 1975 - 184 p.
6. Tsylev L. M; M: Science, Recovery and slag in the blast furnace process. 1970 - 158 p.
7. B. I. Chinas, J. G. Yaroshenko, E. L. Sukhanov [et al.]. - Moscow: Metallurgy Heat blast furnace, 1978 - 248 c.
8. Shvartsman L. A., Zhukovitsky A. A., Moscow. Metallurgy, Beginning Physical chemistry for metallurgists 1974. 352p.